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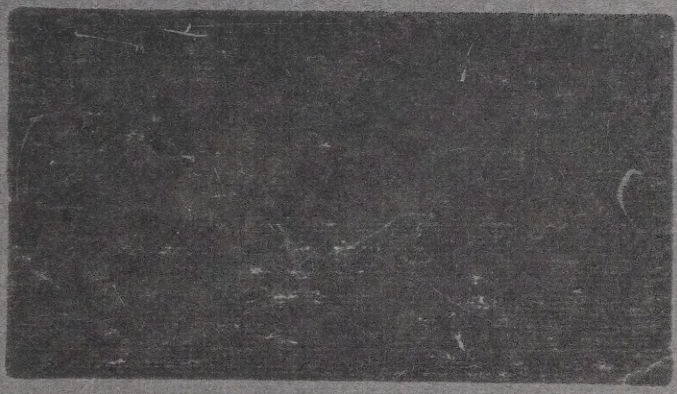

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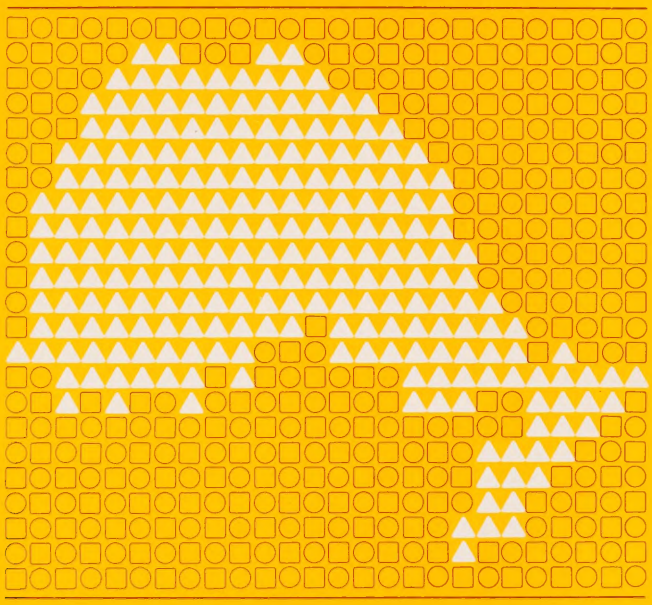
Ontario
Ministry of
Labour

Occupational
Health and Safety
Division

Designated Substances in the Workplace: A Guide to the Benzene Regulation



January 15, 1988

AMENDMENTS TO DESIGNATED SUBSTANCES IN THE WORKPLACE: A GUIDE TO THE BENZENE REGULATION

The Regulation to Amend Certain Regulations made under the Occupational Health and Safety Act, O. Reg. 23/87, was filed with the Registrar of Regulations on January 22, 1987 and came into effect on February 21, 1987. This regulation changed the basis for the calculation of the time-weighted average exposure of a worker to substances designated under section 22 of the Occupational Health and Safety Act to provide that both the weekly (40 hour) and the daily (8 hour) time-weighted average exposures of a worker do not exceed the specified limits.

The Schedules to the following regulations were amended: Lead, Mercury, Vinyl Chloride, Coke Oven Emissions, Asbestos, Isocyanates, Silica, Benzene, Acrylonitrile, and Arsenic.

The new regulation provides for the measurement and calculation of both daily (8 hour) and weekly (40 hour) time-weighted average exposures to designated substances. Under the amended regulations, employers must ensure that the time-weighted average exposure of a worker to the designated substance does not exceed the specified limits both for an 8-hour work day and a 40-hour work week.

Please note that this amendment affects the calculation of time-weighted average exposure and appears in this edition on Page 12.

Designated Substances in the Workplace: A Guide to the Benzene Regulation

February 1986

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ISBN 0-7729-4284-6 6/88 Rev.

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Introduction

The guide has been prepared to help employers, workers, members of joint health and safety committees, supervisors and occupational health personnel meet the requirements of the designated substance regulation respecting benzene in the workplace and to understand the responsibilities this regulation places on all participants in the workplace health and safety system.

The advice in this guide is the interpretation by officials of the Occupational Health and Safety Division of the Occupational Health and Safety Act (the Act) and regulations.

The advice does not have binding effect but is intended to provide general answers to possible questions asked in the context of a specific situation. It is being used by staff of the ministry to assist in the administration of the benzene regulation.

Questions of construction and application will find their ultimate answer given by the courts where a contest ensues as to construction or application of a legislative provision.

The Occupational Health and Safety Division of the Ministry of Labour is responsible for administering the Act. The Regulation respecting Benzene, Ontario Regulation 732/84 was filed with the Registrar of Regulations on November 16, 1984. The provisions relating to the assessment came into force on the date of filing; those relating to control measures came into force on February 14, 1985.

This guide is intended as a supplement to the booklet entitled **Designated Substances in the Workplace: A General Guide to the Regulations** to help employers meet the requirements of the benzene regulation. It reviews the health effects of benzene, its uses and the forms of workplace exposure. In addition, it provides information on the application of the regulation, allowable exposure levels, the assessment and control program and medical surveillance.

It is important that both this guide and the general guide to the regulations, referred to above, be consulted.

For further information on any aspect of the benzene regulation, you should contact the Inspectorate of the Ministry of Labour at the appropriate district office. Appendix 2 lists the addresses and telephone numbers of the District Offices of the ministry. Appendix 3 gives a list of further reading materials that may be helpful in understanding the background to the requirements of the regulation.

1. The Hazards of Benzene in the Workplace

What Is Benzene, Where Is It Found and How Is It Used?

Benzene is an aromatic organic hydrocarbon. Its molecular structure is composed of six carbon atoms and six hydrogen atoms arranged in a symmetrical ring structure. Benzene is a clear colourless liquid with an odour characteristic of aromatic hydrocarbon substances. It is highly flammable and volatile, giving off flammable vapours that are almost three times heavier than air. Benzene may exist as a liquid or a vapour at normal temperatures and pressures and it will freeze to a solid at temperatures below 5.5°C.

The data sheet on benzene prepared for Ministry of Labour inspectors and reproduced in Appendix 1 provides more detailed information on the nature and properties of benzene.

Benzene occurs naturally in the environment. It exists in the atmosphere mainly as a result of automobile exhaust and cigarette smoke. Therefore, everyone is exposed to benzene to some degree. Occupationally-exposed workers are likely to have a much higher intake of benzene than the population at large.

Historically, benzene has been produced as a by-product of coal gasification and metallurgical coke production in steel making. The light oil product from such processes contains benzene, toluene and xylene, and these components are separated by distillation. Today, most benzene is produced from the refining of petroleum.

Benzene is used in the production of styrene and a wide range of synthetic rubbers, plastics and resins. Benzene is also used in the synthesis of phenols, alkyl benzene detergent base materials, cyclohexane and other solvents.

Benzene has application as a solvent in synthetic rubber manufacture and processing and in paints, varnishes, stains, adhesives and sealants. Use of benzene in tire and other rubber goods manufacturing and as a solvent and component of paints and adhesives has declined considerably as a result of concerns about workplace exposure. Nevertheless, it is often present in trace quantities in petroleum and aromatic solvents, some of which have replaced benzene in many uses. Benzene is also a minor component (less than 2.5 per cent) of gasolines sold in Canada.

Why Is Benzene a Health Hazard?

In addition to the health hazard it presents due to its flammability and volatility, benzene, in common with many other toxic substances, may be harmful following a high dose received in a short period of time (acute exposure) or after long-term exposure to lower doses (chronic exposure). In this context, dose means the quantity of benzene absorbed into the body and is primarily a function of the concentration in the workplace air, the duration of exposure and the efficiency of the lungs in transferring benzene into the blood.

Acute exposure to benzene affects the central nervous system, with some irritation of eyes, nose, throat and skin also occurring. Short-term exposures to concentrations of 250 to 500 ppm in air produce symptoms such as dizziness, confusion, headaches and weakness. At higher concentrations, up to 3,000 ppm, euphoria and eventual unconsciousness will result from prolonged exposure. At massive concentrations, around 20,000 ppm or higher, respiratory collapse and death will occur within minutes.

Chronic exposure to benzene affects the blood forming system, particularly the bone marrow. Exposure may adversely affect red cells, white cells and platelets, reducing the number of one or all of these cells in the blood and/or changing their structure. Red cells carry oxygen and nutrients to body tissues, and a reduced red cell count is characterized as anemia. White blood cells are one of the body's defence mechanisms against disease, and a reduced white cell count adversely affects this defence mechanism. Platelets help blood to clot, and excessive and uncontrolled bleeding may result when there is a shortage of these elements in the blood.

Benzene exposure may also induce the onset of leukemia (cancerous blood cells). The presence of leukemic cells in the blood may be preceded by some of the blood disorders previously described or may occur after an apparent recovery from these disorders. Leukemia may also occur without any prior signs of blood disorder.

These chronic effects may be alleviated upon elimination of the benzene exposure. The time required for recovery will depend upon the severity of the blood changes, and, in extreme cases, the recovery period may be several months. In very severe cases no recovery may occur and death may result.

In summary, benzene exposure induces blood and bone marrow toxicity; it has also been found to be clastogenic (causing chromosomal damage) in mice and man, and has shown fetotoxic effects in mice and rats. It has been concluded that benzene exposure in the workplace has the potential to cause blood disorders, anemia, bone marrow diseases and leukemia among exposed workers.

How Is Benzene Absorbed Into the Body?

The predominant route of exposure to benzene in the workplace occurs through breathing vapours and mists. Experiments on human volunteers indicate that about 50 per cent of inhaled benzene is absorbed into the body; however, 30 to 50 per cent of this absorbed

benzene is eliminated in exhaled breath. These rates of absorption and elimination vary greatly from person to person.

Liquid benzene can be ingested by swallowing or by absorption through the skin. Because benzene is a powerful solvent, it will attack the fatty layer of the skin, and continuous skin contact will lead to dermatitis. Benzene will also produce a burning sensation and severe irritation on contact with the eyes.

Some minor ingestion of benzene may occur through contamination of food, drink, chewing gum or cigarettes brought into the work area. It may also occur through eating with contaminated hands or utensils or smoking with contaminated hands.

Rates of absorption and toxic effects of ingested benzene are believed to be similar to those of the inhalation route, although no definitive information is available in this regard.

Similarly, the effects of skin absorption of benzene are not well documented.

Absorbed benzene tends to migrate to fatty tissues and accumulates in bone marrow and the central nervous system.

What Are the Workplaces Where Benzene Exposure May Occur?

Workplaces where benzene exposure may occur encompass the production and usage of benzene itself and the usage and distribution of products that may contain benzene.

Benzene is produced by major petroleum refiners and petrochemical producers in Ontario who have facilities to synthesize and extract benzene from petroleum. Benzene is also produced as a component of light oil by-product from metallurgical coke production at the major integrated steel making operations in Ontario.

More than 80 per cent of the benzene used in Ontario is used to produce styrene. Benzene is also used as a solvent in the production of polybutadiene synthetic rubbers.

Other than in synthetic rubber manufacturing and limited laboratory applications, the use of benzene as a solvent is declining, but benzene is still present in trace concentrations in many of the solvents that have replaced it. The reclamation of solvents by distillation for re-use and the disposal and incineration of waste or surplus solvent materials and other organic industrial liquids also constitute workplaces where benzene exposure may occur. Because benzene is a component of gasoline, gasoline production and distribution present another potential for worker exposure.

Table 1 summarizes the industries where benzene exposure is possible.

Table 1

Types of Industries With Potential for Benzene Exposure

- Petroleum refining
- Coke by-product/metallurgical coke production
- Styrene and synthetic rubber production
- Tire manufacturing
- Rubber goods manufacturing
- Adhesives and sealants manufacturing
- Petrochemical production
- Detergent alkylate production
- Paint manufacturing
- Vegetable oil processing
- Gasoline distribution
- Paper coating and converting
- Footwear manufacturing
- Liquid organic industrial waste disposal
- Miscellaneous solvent usage in laboratories, furniture finishing/re-finishing, solvent reclamation, consumer products

2. The Benzene Regulation

Who Is Covered by the Benzene Regulation?

With the exception of construction projects (explained below) and the delivery of gasoline by a pump into the fuel tanks of motor vehicles and boats or into portable containers, the regulation applies to every employer and worker at a workplace where benzene (or a product containing benzene) is likely to be inhaled, absorbed or contacted by a worker during its transportation or transfer or during its manufacture, processing, use, handling or storage. Table 2 summarizes the types of work with potential for exposure to benzene.

Workers involved in the bulk transfer, transport and off-loading of gasoline remain subject to the regulation because of the potential for high benzene exposure among these workers. Similarly, workers involved in benzene production, coke oven by-products plants and styrene or polybutadiene rubber production are at risk of long-term exposure in excess of 1 ppm benzene, with some workers potentially exposed to concentrations greater than 5 ppm on an 8-hour time-weighted average (TWA) basis.

Industries involved in the use of benzene-containing solvents (paint manufacturers, adhesives formulation, rubber fabrication, paper converting) usually present less potential for occupational exposure to benzene. Such solvents usually contain about 0.1 per cent benzene, and exposures have been shown to be generally less than 1 ppm on an 8-hour TWA.

Table 2

Type of Work With Potential Exposure to Benzene

A. Benzene Production:

- Coke oven by-product unit operations
- Light oil loading, off-loading and bulk storage transfers
- Petroleum refinery benzene production unit operations
- Benzene loading, off-loading and bulk storage transfers
- Benzene and light oil tank sampling, testing and analysis
- Maintenance and inspection of benzene and light oil production units, storage and handling facilities

B. Benzene Usage:

- Benzene transport, loading and off-loading
- Ethyl benzene production unit operations
- Styrene production unit operations
- Polybutadiene production unit operations
- Maintenance and inspection of ethyl benzene, styrene, polybutadiene production units, storage and handling facilities
- Leather workers involved in the usage of benzene as a solvent
- Benzene as a solvent and reagent in laboratories

C. Indirect Usage - Benzene as a Component of Other Products:

- Hydrocarbon solvent uses in paints and coatings, adhesives, rubber goods manufacturing and footwear manufacturing
- Solvent reclamation and recovery unit operations, loading, off-loading storage and transfer of reclaimed solvents
- Liquid industrial waste disposal and liquid organic waste incineration
- Transfer, transport, off-loading of gasoline

Does the Regulation Apply to Construction Projects?

Subsection 3(3)(a) of the regulation specifically exempts an employer and the workers of an employer who is primarily engaged in the business of construction from the requirements of subsection 3(2) and sections 4 through 17 of the regulation.

If the construction project is located at a workplace to which the regulation applies, then the employer responsible for the workplace is required to comply with sections 4 and 5 of the regulation with respect to the workers on the project. Sections 4 and 5 set allowable exposure levels for airborne benzene and determine the conditions under which respirators may be used as a means of complying with these requirements.

Does the Regulation Apply to Gasoline Service Stations and Retail Outlets?

While the regulation does apply to gasoline bulk terminals and the transport and delivery of gasoline to service stations or other premises, it does not apply to the delivery of gasoline into the fuel tank of a motor vehicle, motor boat, or other water craft or into a portable container at a service station or other premises.

What Are the Allowable Airborne Benzene Concentrations?

The benzene regulation requires that workers' time-weighted average (TWA) exposure to benzene be reduced to **the lowest practical level** with the objective of achieving a TWA concentration of not more than **1 part per million (ppm)** by volume or 3.2 milligrams per cubic metre (mg/m^3) of air. The TWA concentration in the workplace shall not exceed **5 ppm** or 16 mg/m^3 and the maximum exposure shall not exceed **15 ppm** or 48 mg/m^3. (See sections 4(1) and (2) of the regulation.)

The time-weighted average exposure of a worker is calculated on the basis of cumulative weekly exposure (40 hours), and cumulative daily exposure (8 hours), as indicated in the Schedule appended to the regulation. Examples of such a calculation are given in Chapter 6 of **A General Guide to the Regulations.**

Employers must use engineering controls, work practices, and hygiene practices and facilities to achieve these exposure values. Only in emergencies or in cases where there are no practical or technically feasible alternatives are these allowable exposures to be achieved through the use of respirators worn by workers.

Chapter 1 of **A General Guide to the Regulations** discusses the lowest practical level of exposure and reads as follows:

> "The lowest practical level will depend on the characteristics of the individual work site. The employer is required to adopt those engineering controls, work practices and hygiene practices that a responsible and prudent employer would put into effect, taking into consideration the plant, equipment, engineering controls and work practices in the workplace, and what can realistically and reasonably be done by way of improvement, modification and replacement.
>
> There are a number of factors that should be considered in determining whether the lowest practical level has been obtained. Some of these factors are:
>
> 1) The extent of the health benefits that will likely be obtained from improvements or modifications to existing engineering controls, etc. in the workplace.

2) The exposure levels that were achieved in the work site in the past.

3) The exposure levels being met in similar work sites.

4) The cost of introducing new engineering controls, or modifying those already in place.

5) The technological feasibility of achieving lower exposure levels."

It is also important to note that the lowest practical level refers to the time-weighted average exposure only. It is likely that short-term fluctuations in exposure above this level will occur.

3. Assessing and Controlling Exposure to Benzene

The Assessment

Chapter 2 of A General Guide to the Regulations describes how to assess the extent to which workers are exposed to benzene. When you are carrying out this assessment, you must note all processes involving benzene and the manner in which benzene is likely to be released into the workplace. In addition to potential sources of airborne benzene, you should be alert to situations that may result in ingestion or skin absorption of benzene. Wherever benzene vapours or liquids are used, pay particular attention to work practices, hygiene practices and facilities.

Table 2 on page 10 presents a list of industrial processes or operations that have varying potentials for worker exposure to benzene. Any work or operation of this nature should be carefully assessed for potential for benzene exposure.

Section 6 of the regulation places an obligation on employers to prepare a written assessment of the nature and potential extent of exposure of workers to benzene in the workplace. In many cases, whether or not an assessment is actually carried out will depend on whether the employer is aware of the potential for benzene exposure. It is therefore important to have available material safety data sheets (MSDS) on all chemicals, materials and solvents used in the workplace to determine whether benzene is present.

A written assessment report must be prepared and should include a summary of the information gathered and the analysis of these data. The report must state whether there is actual or potential

exposure of workers to benzene and whether their health may be affected. The conclusion must indicate whether or not a control program is necessary. More information on the conclusions that may be reached is outlined on page 26 of **A General Guide to the Regulations.**

It may be necessary to include air sampling as part of the assessment for benzene. Chapter 6 of **A General Guide to the Regulations** explains in detail the procedures for air monitoring that should be used to determine the concentration of benzene in workplace air. The benzene regulation references a Measurement Code that specifies methods and procedures to be used for air sampling and analysis required to determine compliance with the exposure limits prescribed by the regulation and to meet the requirements of the benzene control program if one is required.

In carrying out air sampling for the assessment, it may not be necessary to use the methods specified in the Measurement Code. Direct reading instruments, including colorimetric indicator tubes, will often be adequate for determining the general degree of benzene exposure. Such instruments are, however, subject to a considerable degree of inaccuracy due to interference of other substances, inherent variability or insensitivity. Should an accurate determination of exposure be required, the methods and procedures specified in the Measurement Code should be used.

The Control Program

Chapter 3 of **A General Guide to the Regulations** describes how to develop a written control program in consultation with a joint health and safety committee.

If a benzene control program is required, it must include engineering controls, work and hygiene practices, administrative controls and personal protective measures to reduce the exposure of workers to benzene.

Engineering Controls

Engineering controls can be grouped into the categories described in Chapter 4 of **A General Guide to the Regulations**. They include:

- material substitution
- process changes
- enclosure or isolation of emission sources
- local exhaust ventilation
- general ventilation

Material Substitution

It may be possible to eliminate benzene from the workplace by replacing it with a less toxic material. This may be particularly true of solvent applications of benzene and in situations where it is possible to specify a non-benzene solvent or a solvent with a minimal benzene content. It is important, however, to carefully consider the toxicity and workplace hazard that may be imposed by the substitute material.

The trend to the use of solvents with minimal benzene content has accelerated in the last few years. Reduction of worker exposure is achieved by the use of solvents with low or negligible benzene content and through the use of local ventilation. Companies are using benzene substitutes such as toluene and hexane as well as low benzene content naphthas with benzene concentrations typically ranging from 0.01 to 0.5 per cent. In these workplaces, TWA exposures to benzene may be reduced to less than 0.5 ppm as a result of these actions.

Material Safety Data Sheets (MSDS) should be requested from solvents manufacturers or suppliers to obtain specific information on the benzene content of available solvent formulations. In this way decisions can be made on product substitutions to reduce benzene exposure in the workplace.

Process Changes

Various alternatives can be considered to reduce benzene exposure through changes in production or materials handling processes. Among these are:

- the use of closed systems for transfers of benzene
- bottom-loading of tank cars and trucks
- venting of tanks and storage vessels outside enclosed workplaces
- modification of loading arms and the installation of a totally sealed vacuum system in railcar loading
- double mechanical seals on pumps
- floating roof storage tanks with double seals
- closed loop sampling systems
- covering and sealing of sewer drains and sumps
- scrubber eductors or carbon filters on plant vents and stacks
- process unit leakage control around pumps, seals, flanges, valves, etc.
- isolation of sump skimming, pump out and draining operations.

Examples of ways in which various industrial sectors and plants have addressed the reduction of benzene exposure through process changes are discussed below:

Use of Vapour Leakage Control and Outside Vents

Adhesives are manufactured by batch processes in "kettles" that contain the solvent and to which the solid ingredients are added via a hopper-type feed. Many rubber adhesives require "mastication" of the rubber compound with the solvent in the kettle, using rapidly turning blades driven by powerful motors. This process generates a great deal of heat, causing volatilization of some of the solvent. These solvent vapours can be vented to the outside to alleviate

worker exposure, and the use of effective seals around openings and pipe flanges can reduce fugitive emissions.

Closed Loop Sampling

Sampling of process streams and storage tanks for quality control purposes can result in a certain amount of exposure. Elimination of the need to flush sampling lines by the use of sample-loops, and of the need to gauge tanks manually by installation of remote level indicators, will reduce exposure. In enclosed areas, control of emissions to the work environment is achieved by adsorption of vapour at vents and by ventilation.

Absorption, Adsorption and Condensation

Absorption, adsorption and condensation of hydrocarbons are important recovery techniques in the petrochemical industry. In absorption processes, benzene vapours are dissolved in a non-volatile solvent such as oil or furnace oil, which is subsequently steam stripped to recover the benzene. Benzene may also be recovered by condensing vapours in a water-cooled condenser. Adsorption involves the use of a granular solid medium such as activated carbon, which selectively attracts and retains benzene in the vapour stream for subsequent recovery by heating or steam stripping.

Venting to Flare Systems

Most petrochemical processes have pressure release vents, both as a protective measure and, in some cases, as a process control device. Sudden or unexpected upsets and scheduled shut-downs in process units can produce gas in excess of the capacity of the hydrocarbon recovery system. If the vented gas is flammable, as is the case for benzene, it may be routed to the flare system and burned. By venting to the flare, emissions to work areas can be avoided. In addition, the coupling of vents to the flare system enables vents to

be set to operate at a lower pressure, thereby reducing pressure in process equipment and minimizing fugitive leaks from seals and gaskets.

Mechanical Pump Seals

One of the largest (and yet most difficult to control) categories of benzene emissions from refinery and petrochemical operations is fugitive emissions. The sources of such leaks are multiple, some of which, such as seals, gaskets and vents, have been mentioned already. Pumps and compressors required to move liquids and gases can leak products at the point of contact between the moving shaft and the stationary casing. Two types of seals commonly used in industry are packed seals and mechanical seals. The latter are more expensive but can reduce losses significantly, commonly by 90 per cent. In potential high hazard applications, such as the pumping of pure benzene, double seal construction is used, with provision made for venting the vapours that leak past the first seal.

Process Unit Leakage Control

Good process plant design provides for the immediate capture of accidental and, at times, inevitable, spills of benzene-containing liquids by means of spill trays and drip pans around pump seals and glands, the provision of berms and impoundments around storage tanks and by minimizing the number of flanges and interconnects where leakage can occur. Provision should also be made for conducting the spilled liquids to enclosed sumps and drains for subsequent treatment and disposal.

Floating Roof Storage Tanks

Benzene, gasoline and hydrocarbon solvents are stored in large volume facilities. The most frequently used type of storage tank is a vertical, cylindrical, fixed-roof vessel with a conical or domed roof. They are usually vented to the atmosphere and may represent

a significant source of hydrocarbon losses. Uncontrolled storage tanks of this type can account for half of the gasoline emissions from a bulk terminal. These losses occur from evaporation and breathing of the tank during filling and emptying. The best technology for control of tankage losses consists of (1) floating a rigid cover on the surface of the stored liquid to reduce evaporation and eliminate the vapour space and (2) containing the tankage vapours within a sealed system that incorporates a variable vapour space to provide surge capacity. The efficiency of these approaches to controlling tank emissions is greater than 90 per cent when compared to uncontrolled tankage losses. Pure benzene is commonly stored in these floating-roof type facilities.

Loading Arm Modifications and Vapour Recovery

Benzene, volatile solvents and gasoline are distributed by pipeline, tanker trucks, railroad tank cars and marine tankers. Significant vapour exposure can occur when the liquids are loaded into transport vehicles. Except for tanker trucks, the most common filling method is overhead loading. Worker exposure occurs because of vapour displacement as the tank is being filled through the open hatch and because visual monitoring of the liquid level is usually required. Various types of vapour collectors have been developed for use during overhead loading. They are essentially plug-shaped devices that are inserted into the hatch opening. The hydrocarbon flows through a central pipe in the device into the tank compartment. This pipe is surrounded by an annular space into which flow the displaced vapours. The annular space is, in turn, connected to a hose leading to a vapour disposal system. In Ontario such vapour recovery systems have been considered to be impractical because of the varied hatch geometrics that exist on transportation vehicles, and because of cost.

Fill lines used in benzene loading operations will contain benzene when the operation is terminated. Rather than allow this residual liquid to evaporate or to spill out of the lines it can be drained,

either by gravity or by the application of suction, into a covered sump for subsequent recovery or disposal. Alternatively, benzene losses from line drainage following bulk transfers may be reduced by the application of "dry break flanges" on transfer line couplings. These couplings automatically attach a mechanical seal on the line as they are disconnected.

Bottom-Loading

Many gasoline tank trucks are fitted with bottom-loading capabilities. These facilities have loading arms with flexible tubes that connect to self-sealing valves on the side of the tank truck. Each filling tube has an automatic metering system, which is set by the driver/salesman to prevent spillover. The system is activated by a dead-man button located in an operator shack adjacent to the filling station. Some bottom-loading racks are also equipped with vapour recovery systems.

Enclosure/Isolation

Enclosure or isolation of benzene emission sources in the workplace can be accomplished through installation of enclosures around conveyor systems, driers and handling systems where solvent laden articles are being transferred, through isolation of solvent storage from the workplace and through the direction of benzene process vents and purges to storage or disposal. The maintenance of these enclosures at a slightly negative pressure through exhaust ventilation or vapour recovery collection system will also serve to ensure that vapours do not escape into the workplace from the enclosure.

In some petrochemical plants and refineries the process control room is maintained at a slight positive pressure to reduce the entry of vapours from the outside plant. As the operators spend a considerable portion of their shift in the control room, worker exposure to benzene is thus minimized.

Solvent storage in enclosed areas of a process plant present a potential for exposure to benzene vapours. Enclosure of such storage by a shed or room and the use of ventilation systems to direct vapours outside the building are effective means of reducing exposure to the benzene vapours.

Ventilation

In enclosed plants involved in fabrication processes using benzene and benzene-containing solvents, local ventilation at the point of emission can be used to reduce worker exposure.

Local exhaust ventilation must be provided at work stations and operations where other methods of reducing benzene exposure to acceptable levels have proven to be inadequate.

Local exhaust ventilation hoods must be located as close to the source of benzene emissions as possible. Such ventilation would normally be applicable to work stations involving handling of benzene or benzene-contaminated materials as a solvent, such as in laboratory analysis, around adhesive formulation kettles and at loading and unloading stations, on assembly line driers and rubber curing operations.

A good general workplace ventilation system is also important to dilute air contaminants and, indeed, may be the only ventilation necessary.

Regular maintenance of local exhaust and general ventilation systems should include checks for air leakage and condensation of benzene solvent vapours as well as routine checks of the fan and collector system. The location, height and dispersion of both local exhaust and general ventilation system outlets should be reviewed and approved by the Ministry of the Environment.

Standard practices in the design of industrial exhaust systems are described in reference texts such as **Industrial Ventilation, A Manual of Recommended Practice**, published by the American Conference of Governmental Industrial Hygienists.

Work Practices and Hygiene Practices

Inadvertent absorption of benzene into the body through swallowing, inhalation and skin contact can be avoided by diligent application of good hygiene and work practices. These practices should incorporate written procedures and plant rules addressing matters such as:

- consumption of food and drink at work stations
- personal cleanliness and hygiene
- equipment maintenance
- safety practices and emergency procedures
- housekeeping practices, spill prevention and clean-up
- smoking at work stations and personal hygiene associated with smoking.

The position of the operator during filling operations has an important influence on exposure, a factor that is particularly important in top-loading. Work procedures that require an operator to make only periodic visual checks on loading progress rather than to stand continuously on the loading platform reduce exposure. The use of a dead-man button remotely situated from the loading point, coupled with metering of liquid delivered, in bottom-loading facilities is an effective way of reducing exposure. Liquid levels in tank cars can be monitored by the use of probes that terminate loading operations at a pre-set level or by the use of magnetic gauges that give the loader a remote visual check of the level.

The use of metering pumps, level indicators and dead-man buttons to control loading operations also reduces the danger of fire from overfilling.

Administrative Controls

As noted in **A General Guide to the Regulations**, administrative controls relate primarily to personnel practices and management strategies that can reduce the exposure of individual workers to benzene. They may include:

- the scheduling of maintenance, equipment replacement, pump repair or other operations with potential for high benzene exposure for periods when few workers are present;
- the rotation of work schedules to limit the time that any worker is exposed to benzene; and
- the establishment of work-rest schedules that limit the duration of worker exposure to benzene at an individual work station.

Personal Protective Equipment

The use of personal protective equipment should be regarded as a supplementary measure to engineering controls and other procedures for controlling emissions of benzene into the workplace.

Personal protective equipment includes protective gloves, clothing, footwear, face and eye shields and respirators. The type of protection selected must be appropriate to the job site in question, be compatible with prevention of exposure or contact with benzene and take into consideration worker comfort and potential for causing heat stress. Reference should be made to the data sheet on benzene that appears in Appendix 1 for information on protective measures, equipment and clothing that are suitable for controlling exposure to benzene.

In situations where local exhaust ventilation or general ventilation is effective in reducing airborne levels of benzene, but the potential for skin contact remains, gloves and footwear that provide an

acceptable barrier to benzene penetration should be worn together with work clothing that is removed at the end of the work shift.

When it is necessary that respirators be worn they must be supplied by the employer, and the employer must provide training and instruction to the worker in the proper care and use of the respirator.

The Type of Respirator Required

The type of respirator should be appropriate for the level of airborne benzene that is of concern. Use of respirators should conform to the practices outlined in Chapter 5 of **A General Guide to the Regulations**.

The type of respirator required for various levels of airborne benzene and the general requirements for the use of respirators are detailed in the **Code for Respiratory Equipment for Benzene**, dated October 29, 1984 and appended to the regulation. Respirators must meet or exceed the following requirements:

Concentration of Airborne Benzene	Type of Respirator Required
Less than or equal to 50 ppm	Air purifying chemical cartridge respirator with organic vapour cartridges and half or full facepiece.
Greater than 50 ppm	Supplied air respirator with a full facepiece or hood in pressure-demand or other positive pressure or continuous flow mode (Type C) or self-contained breathing apparatus with a full facepiece operated in pressure demand.
Escape	Any escape self-contained breathing apparatus or any air purifying chemical cartridge respirator with organic vapour cartridges and half or full facepiece.

Notes:

1. Vapours can be defined as the gaseous form of a substance which is normally either a liquid or a solid at ordinary temperatures and pressures.

2. Since the odor threshold of benzene is 5 ppm or higher, organic vapour cartridges must be replaced at the beginning of each work shift or after 8 hours use.

3. Respirators need not be worn if the time-weighted average exposure of a worker is less than 5 ppm assuming that the maximum exposure does not exceed 15 ppm. However, if a worker wishes to use a respirator, the correct type of respirator must be worn.

4. Supplied air respirator does not include a powered air-purifying respirator.

4. Measuring Airborne Benzene

Chapter 6 of **A General Guide to the Regulations** describes the reasons for the measurement of airborne concentrations of benzene in the workplace, the purposes for which these measurements are applied and how to calculate the time-weighted average exposure of a worker.

The **Code for Measuring Airborne Benzene**, dated October 29, 1984 and appended to the regulation, identifies the sampling procedures and equipment and the analysis methods and calculations to be used to determine compliance with the exposure limits prescribed by the regulation and to meet the requirements of the benzene control program if such a program is required. Unless an employer can demonstrate that any alternative methods and procedures used are equal to or better than these, with respect to the factors of accuracy and precision, the standard practices laid out in the Measurement Code must be followed.

5. Medical Surveillance For Exposure to Benzene

The benzene regulation requires that the control program provide for a medical surveillance program, which must include:

- pre-employment, pre-placement and periodic medical examinations
- clinical tests
- health education
- record keeping

The requirements are detailed in the **Code for Medical Surveillance of Benzene Exposed Workers**, dated October 29, 1984 and appended to the benzene regulation.

The medical surveillance program is designed to protect the health of workers through the detection of any adverse health effects due to benzene exposure and by the education of all staff on the health hazards associated with benzene exposure.

Section 3 of the Code explains what the physician should look for at the pre-placement and periodic medical examinations. Medical records kept by the physician should include the information listed in section 6 of the Code. This program is to be undertaken at the employer's expense.

A detailed outline of the general requirements for medical surveillance are contained in Chapter 7 of **A General Guide to the Regulations**.

Clinical Tests

Section 4 of the Code explains the clinical tests that are used in assessing the worker's benzene exposure and fitness for continued exposure to benzene. These include hematological (blood) tests, which are designed to reveal blood cell abnormalities that may be attributable to benzene exposure. Notwithstanding the results of these tests, a benzene-exposed worker must be removed from exposure if any other symptoms or signs of benzene toxicity are present.

The Examining Physician

The benzene regulation does not stipulate who shall be the examining physician, thus allowing the worker to select the doctor of his or her choice. As a result, the examining physician may be the company doctor, a private consultant with whom the employer contracts services, a physician on the staff of a clinic or the personal physician of the worker. Every examining physician must know the content of the Code for Medical Surveillance and his or her responsibilities. Where there is more than one examining physician, a physician should be appointed in a co-ordinating role. The role of the co-ordinating physician, who should be selected jointly by the employer and the joint health and safety committee, should be to standardize examination and test procedures, maintain medical records and identify any trends in examination and test results.

Physician Reporting Protocol

The regulation requires the examining physician to advise the employer whether the worker is fit, fit with limitations or unfit for exposure to benzene. This determination is a professional judgement based on the results of medical examinations and clinical tests. **The physician must give this opinion without disclosing to the employer the results of the examinations or tests.**

The regulation requires the physician to advise the joint health and safety committee in writing of the results of clinical tests, along with an opinion as to how these tests should be interpreted and an opinion as to the fitness of the worker for exposure. In all such cases, the committee must receive this information on a confidential basis. If the physician has advised the employer that a worker is fit with limitations or unfit, he or she must also report this information to the Chief Physician of the Occupational Health Medical Service of the Ministry of Labour. These requirements are specified in sections 16(1), 16(2), 16(3) and 16(5) of the regulation.

6. Appendices

Appendix 1 -- Data Sheet for Inspectors

DATA SHEET FOR INSPECTORS

BENZENE

CAS REG. NO. 71-43-2

OTHER NAMES

Benzol, Benzole, Cyclohexatriene, Phene, Phenyl Hydride, Pyrobenzol

NOTE: Benzin, petroleum benzin, and benzine are names for a petroleum distillate containing aliphatic hydrocarbons and should not be confused with benzene.

TRADE NAMES

None

POTENTIAL EXPOSURE

USES: Benzene is used in the production of styrene, phenol, cyclohexane and other organic chemicals. It is also present in gasoline at concentrations up to 5% and in some hydrocarbon solvents (toluene, xylenes, petroleum naphtha, petroleum spirits, commercial turpentine). The benzene content in solvents used in some rubber cements, paints and varnishes varies from 0.04 to 2% but is generally about 0.1%.

OCCUPATION(S):
Adhesive makers
Asbestos product impregnators
Catalyst formulators
Coke by-product plant workers
Detergent makers
Dye makers
Furniture finishers
Gasoline handlers
Glue makers
Laboratory workers
Linoleum makers
Paper converters
Petrochemical workers
Putty makers
Refinery workers
Rubber makers
Welders

STORAGE

Store in a cool, well-ventilated location away from main work-sites.

Benzene containers should be properly labelled and tightly closed.

Benzene containing drums should be solidly supported and grounded.

INCOMPATIBLE WITH: Strong oxidizers such as chlorine, bromine with iron, ozone and perchlorates

LABELLING MUST BE ADEQUATE

EXPOSURE LIMITS

TWAE: Worker exposure to airborne benzene shall be reduced to the lowest practical level with a view to achieving a time-weighted average of at least 1 ppm or 3.2 mg. of benzene per m^3 of air by volume, and in any event shall not exceed a TWA of 5 ppm or 16 mg. benzene per m^3 of air.

MAXIMUM: 15 ppm, 48 mg/m^3

IMMEDIATE DANGER LEVEL: 2000 ppm, 6400 mg/m^3

PROPERTIES

FORMULA: C_6H_6

DESCRIPTION: colourless liquid at room temperature

ODOUR: characteristic, pleasant, aromatic

Odour Threshold: 4.5 ppm

SPECIFIC GRAVITY (20°C): 0.88

VAPOUR DENSITY (Air = 1): 2.7

BOILING POINT: 80.1°C

FIRE AND EXPLOSION

Benzene is an extremely flammable and highly volatile liquid. Leaks or spills can easily result in the formation of explosive mixtures.

EXTINGUISHING MEDIA: Use dry chemical, carbon dioxide, or foam. Water is not effective as an extinguishing agent, but a water spray should be used to keep fire-exposed containers cool.

FLASH POINT (closed cup): -12 to 10°C

AUTO-IGNITION TEMPERATURE: 490°C

EXPLOSIVE LIMITS (By volume in air):

Lower 1.4% Upper 7.1%

HAZARDOUS DECOMPOSITION PRODUCTS: Incomplete combustion results in the formation of carbon monoxide.

LEAKS, SPILLS AND DISPOSAL

Evacuate area of spill.
Stay upwind of spill.
Wear respirator and protective clothing in the spill area.
Remove all ignition sources and ventilate area.
Absorb spilled liquid in sand or inert absorbent.
Large quantities should be disposed by a licensed solvent disposal company.
Small quantities can be incinerated.

NEUTRALIZING CHEMICALS: Not Applicable

BENZENE
CAS. REG. NO. 71-43-2
(cont'd.)

BENZENE

CAS. REG. NO. 71-43-2

SAFETY PRACTICES

PRECAUTIONS:

Reduce exposure to the lowest practical level.
Use less hazardous benzene-free substitutes where possible.
Eliminate all sparks, flames and ignition sources.
Do not smoke in areas of use.
Inform workers of fire and health hazards.

VENTILATION:

Exhaust ventilation and process enclosure should be used to control work place exposure.

Use spark-proof fans.

REPAIRS AND MAINTENANCE:

Measure concentration before entering a confined space.
Wear suitable protective clothing and respiratory equipment (see safety equipment section).
Use only non-sparking tools.
Use only explosion proof equipment and instruments.

SAFETY EQUIPMENT

Impervious type protective clothing should be available where physical contact is unavoidable. Gloves, boots and other protective clothing must not be rubber because benzene dissolves natural rubber. Clothing and footwear should be anti-static and fire retardant. Eyewash facilities should be installed. Respiratory devices should be immediately accessible for use in emergencies.

RESPIRATORS:

CONC. (ppm)	TYPE
Less than or equal to 50 ppm	Air purifying chemical cartridge respirator with organic vapour cartridges and half or full facepiece.
Greater than 50 ppm	Supplied air respirator with a full facepiece or hood in pressure-demand or other positive pressure or continuous flow mode (Type C) or self-contained breathing apparatus with a full facepiece operated in pressure demand.
Escape	Any escape self-contained breathing apparatus or any air purifying chemical cartridge respirator with organic vapour cartridges and half or full facepiece.

NOTE: Respirators must not be a substitute for other means of engineering control (e.g., adequate ventilation).

HEALTH EFFECTS - PROTECTION - FIRST AID

EXPOSURE	SYMPTOMS	PROTECTION	FIRST AID
EYES:	Irritation; liquid causes burning sensation	Safety glasses, goggles, face-mask and eye-wash facilities	Wash with water for 15 minutes. Contact physician.
SKIN:	Irritation, redness and blistering; dry scaly dermatitis from repeated exposure	Impervious protective clothing and gloves (see safety equipment section)	Remove contaminated clothing. Wash skin with soap and water.
INHALATION:	Irritation of nose and respiratory tract. Transient euphoria, headache, nausea, drowsiness, vertigo, confusion, coma and in extreme cases death from respiratory failure.	Ventilation, respirators (see safety equipment section)	Remove to fresh air. Apply artificial respiration if necessary. Contact physician.
INGESTION:	Coughing, headache, dizziness, nausea, vomiting unconsciousness	No food or drink in area of use, good hygiene practices	Do not induce vomiting. Contact physician immediately. Rinse mouth.
LONG TERM:	Repeated exposure to benzene can result in the development of blood disorders which can include aplastic anemia and leukemia.		

ADDITIONAL INFORMATION

This data sheet is intended to impart basic information only. If additional information or specific references concerning benzene are required contact your local field office of the Occupational Health Branch.

Appendix 2 – Regulations made under the Occupational Health and Safety Act Revised Statutes of Ontario, 1980, Chapter 321 as at June 1, 1988

A. Designated Substances

Acrylonitrile:	O. Reg. 733/84 as amended by O. Reg. 23/87.
Arsenic:	O. Reg. 176/86 as amended by O. Reg. 23/87.
Asbestos:	O. Reg. 570/82 as amended by O. Reg. 655/85, O. Reg. 23/87.
Asbestos on Construction Projects and in Buildings and Repair Operations:	O. Reg. 654/85.
Benzene:	O. Reg. 732/84 as amended by O. Reg. 23/87.
Coke Oven Emissions:	O. Reg. 517/82 as amended by O. Reg. 23/87.
Ethylene Oxide:	O. Reg. 146/87.
Isocyanates:	O. Reg. 455/83 as amended by O. Reg. 23/87.
Lead:	O. Reg. 536/81 as amended by O. Reg. 23/87.
Mercury:	O. Reg. 141/82 as amended by O. Reg. 23/87.
Silica:	O. Reg. 769/83 as amended by O. Reg. 23/87.
Vinyl Chloride:	O. Reg. 516/82 as amended by O. Reg. 23/87.

B. General

Biological or Chemical Agents, Control of Exposure to:	O. Reg. 654/86 as amended by O. Reg. 707/86, O. Reg. 339/87.

Appendix 2 – (cont'd)

Inventory of Agents or Combinations of Agents for the Purpose of Section 21 of the Act:	R.R.O. 1980, Reg. 693.

C. Hazardous Physical Agents

X-Ray Safety:	O. Reg. 632/86.

D. Safety Regulations

*Construction Projects:	R.R.O. 1980, Reg. 691 as amended by O. Reg. 635/86 (Re: Crane Operators).
Elevated or Suspended Work Places on Building Facades:	O. Reg. 156/84.
*Industrial Establishments:	R.R.O. 1980, Reg. 692.
*Mines and Mining Plants:	R.R.O. 1980, Reg. 694 as amended by O. Reg. 226/83, O. Reg. 569/83, O. Reg. 365/86, O. Reg. 450/86, O. Reg. 569/86, O. Reg. 654/86, O. Reg. 258/87.
Critical Injury Defined: (for reference see * above)	O. Reg. 714/82.
Diving Operations:	O. Reg. 634/86.
Fire Fighters Protective Equipment:	O. Reg. 125/83.
Oil and Gas-Offshore:	O. Reg. 633/86.
Teachers:	O. Reg. 191/84.
University Academics and Teaching Assistants:	O. Reg. 307/84.

For a complete reference to the Regulations made under the Occupational Health and Safety Act, recourse should be made to the Annual Consolidated Index to the Regulations of Ontario.

Appendix 3 – Ministry of Labour District Offices

Barrie
Industrial Health and Safety
114 Worsley Street
L4M 1M1
(705) 722-6642
1-800-461-4383*

Elliot Lake
Mining Health and Safety
Algo Centre
151 Ontario Avenue
P5A 2T2
(705) 848-2885

Hamilton
Industrial Health and Safety
119 King St. W., 8th Floor
L8N 3Z9
(416) 521-7736
1-800-267-0915
Construction Health and Safety
105 Main St. E., Suite 807
(Terminal Tower), L8N 1G6
(416) 521-7746

Kingston
1055 Princess Street, Suite 105
K7L 1H3
Construction Health and Safety
Industrial Health and Safety
(613) 545-4340
1-800-267-0915*
Mining Health and Safety
(Suite 301)
(613) 545-4335
1-800-267-0915*

Kirkland Lake
Mining Health and Safety
38 Second Street
P2N 1R1
(705) 567-5241

Kitchener
824 King Street West, 4th Floor
N2G 1G1
Construction Health and Safety
Industrial Health and Safety
(519) 744-8101
1-800-265-2373*

London
205 Oxford Street East
N6A 5G6
Construction Health and Safety
Industrial Health and Safety
Mining Health and Safety
(519) 439-3231
1-800-265-4707*

North Bay
Industrial Health and Safety
1500 Fisher Street
Northgate Square
P1B 2H3
(705) 476-2711
1-800-461-1654*

Ottawa
2197 Riverside Drive
K1H 7X3
Construction Health and Safety
Industrial Health and Safety
(613) 523-7530
1-800-267-1916*

Peterborough
139 George Street North
K9J 3G6
Construction Health and Safety
(705) 742-3436
1-800-461-1425*
Industrial Health and Safety
(705) 876-1800
1-800-461-1425*

St. Catharines
205 King Street
L2R 3J5
Construction Health and Safety
Industrial Health and Safety
(416) 682-7261
1-800-263-7260*

Sarnia
Industrial Health and Safety
700 Christina Street North
N7V 3C2
(519) 336-1200
1-800-265-1416*

Sault Ste. Marie
390 Bay Street
P6A 1X2
Construction Health and Safety
Industrial Health and Safety
(705) 949-3331
1-800-461-7268*

Sudbury
199 Larch Street
P3E 5P9
Construction Health and Safety
Industrial Health and Safety
(705) 675-4455
1-800-461-4000*
Mining Health and Safety
(705) 675-4464
1-800-461-4000*

Sudbury
260 Cedar Street
P3B 3X2
Mining Health and Safety
(Chief Engineers)
(705) 675-4468
1-800-461-4000*

Thunder Bay
435 James Street South
P7E 6E3
Construction Health and Safety
Industrial Health and Safety
(807) 475-1691
1-800-465-5016(7)*
Mining Health and Safety
(807) 475-1675
1-800-465-5016(7)*

Timmins
273 Third Avenue
P4N 1E2
Construction Health and Safety
Industrial Health and Safety
Mining Health and Safety
(705) 267-6231
Zenith 57740* (Mining)

Toronto East
2500 Lawrence Avenue East
Scarborough
M1P 2R7
Construction Health and Safety
Industrial Health and Safety
(416) 750-3557

Toronto West
2 Robert Speck Parkway
Mississauga
L4Z 1H8
Construction Health and Safety
Industrial Health and Safety
(416) 273-7800
1-800-268-2966(7)*

Windsor
500 Ouellette Avenue
Suite 305
N9A 1B3
Construction Health and Safety
Industrial Health and Safety
(519) 256-8278
1-800-265-5140(4)*

Health and Safety Support Services Branch Laboratory
101 Resources Road
Weston, Ontario
M9P 3T1
(416) 235-5958

Head Office
400 University Avenue
Toronto, Ontario
M7A 1T7

Construction Health and Safety
(416) 965-7161
1-800-268-8013*

Industrial Health and Safety
(416) 965-4125
1-800-268-8013*
Mining Health and Safety
(416) 965-1328
1-800-268-8013*

Health and Safety Support
Services Branch
(416) 965-3211
1-800-268-8013*
Program Development Unit
(416) 965-8710
1-800-268-8013*

*Toll free line. For callers located within the area code but outside the local calling area of this city. Consult the blue pages in your local telephone directory for additional information. The Ministry may also be reached 24 hours a day through the emergency telephone number in Toronto (416) 965-6664.

Appendix 4 – Supplementary Reading Materials

1. Occupational Health Implications of Benzene in Ontario. Prepared by Michael Holliday and Associates under contract to the Ontario Ministry of Labour, October 1979.

2. An Analysis of Health Effects of Benzene and Recommendations for an Occupational Standard. Health Studies and Services Branch, Ontario Ministry of Labour, July 1983.

3. Report to the Advisory Council on the Designation of Benzene in Ontario, Volume 1. Ontario Ministry of Labour, March 12, 1984.

4. Summary of Information and Data Gathered by the Ministry of Labour After the October 11, 1983 Public Meeting on the Proposed Benzene Regulation. Occupational Health and Safety Division, Program Development Unit, October 1984.

5. A Guide for Joint Health and Safety Committees and Representatives in the Workplace. Ontario Ministry of Labour, March 1983.

6. A Guide to the Occupational Health and Safety Act. Ontario Ministry of Labour.

Notes

Ontario
Ministry of
Labour

Occupational
Health and Safety
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